X-ray Surveys

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With thanks to John Silverman,
N. Brandt & G. Hasinger (ARA&A 2005), Jian Wu

Disclaimer

This review, like so many surveys, will be

- *incomplete*
- *biased*

Survey types include

KNOWN OBJECTS

- pointed sample surveys
- raster/mosaic/tiling of individual objects

SERENDIPITOUS

- deep pencil beam serendipitous
- raster/ mosaic/ tiling of ‘blank sky’ region
- scattered field archival
- all-sky

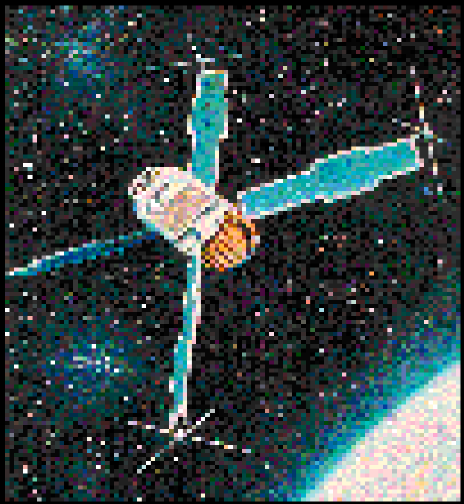
I’ll speak only about serendipitous, extragalactic X-ray surveys from focusing telescopes, and almost exclusively about AGN

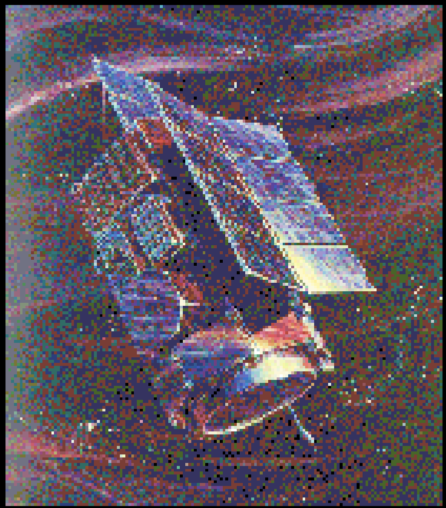
Outline

- History of large surveys
- log*N*-log*S*
- The Cosmic X-ray Background
- Survey Science Motivations
- Advantages and characteristics of X-ray selection
- Current surveys, Deep and Wide
- Multiwavelength followup
- Source types
- Science Results

Early X-ray Surveys

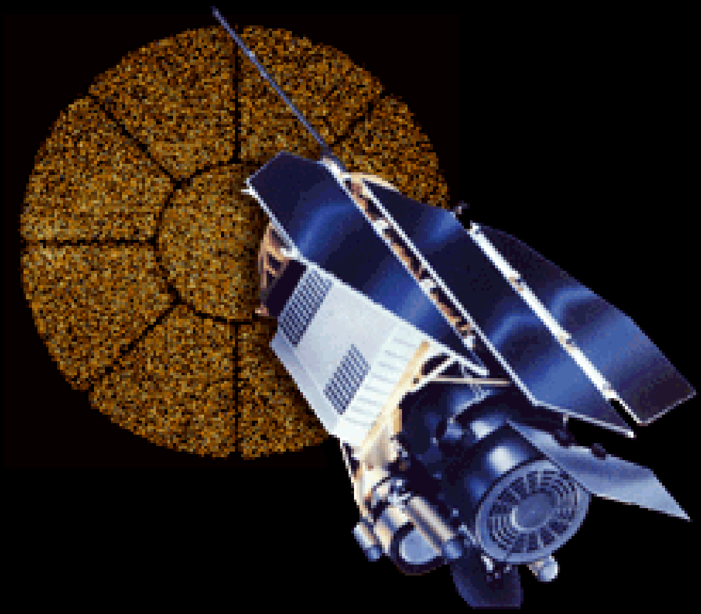
- Uhuru (1970-1973)   [2-20 keV]
- Ariel-V (1973-1980)   [0.3-40 keV]
- HEAO-1 (1977-1979) [0.2keV-10MeV]





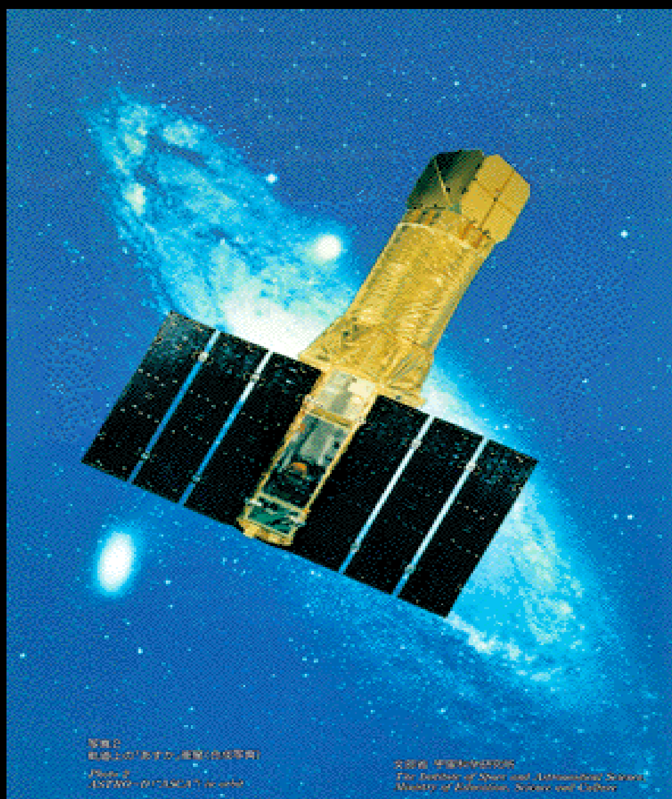
Soft X-ray Surveys

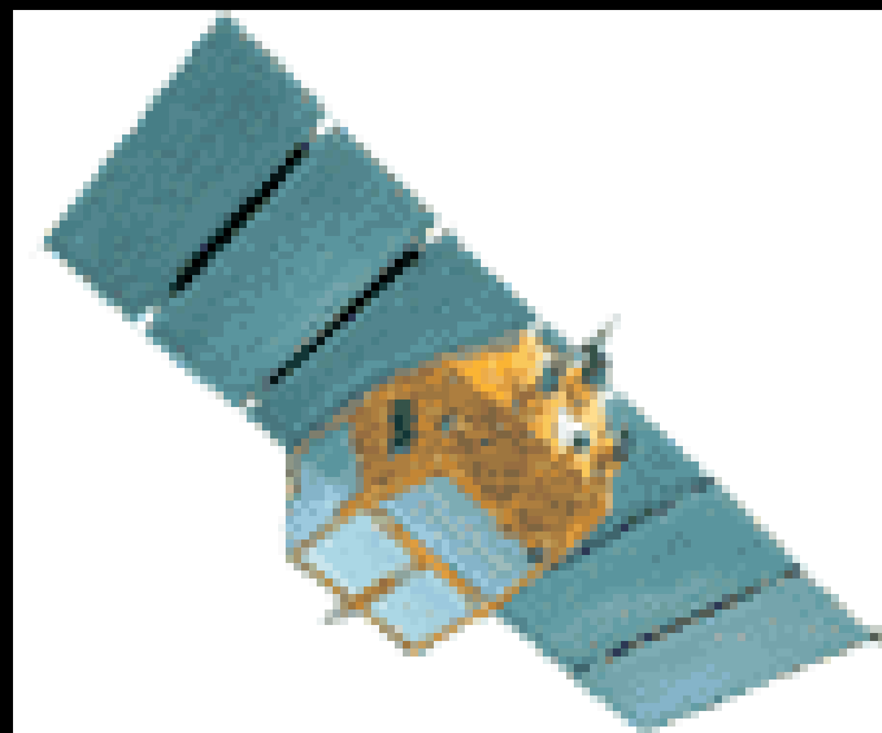
- Einstein (1978-1981) [0.2-20 keV]
  aka HEAO-2, first imaging telescope
- ROSAT (1990-1999) [0.1-2.5 keV]



Hard X-ray surveys

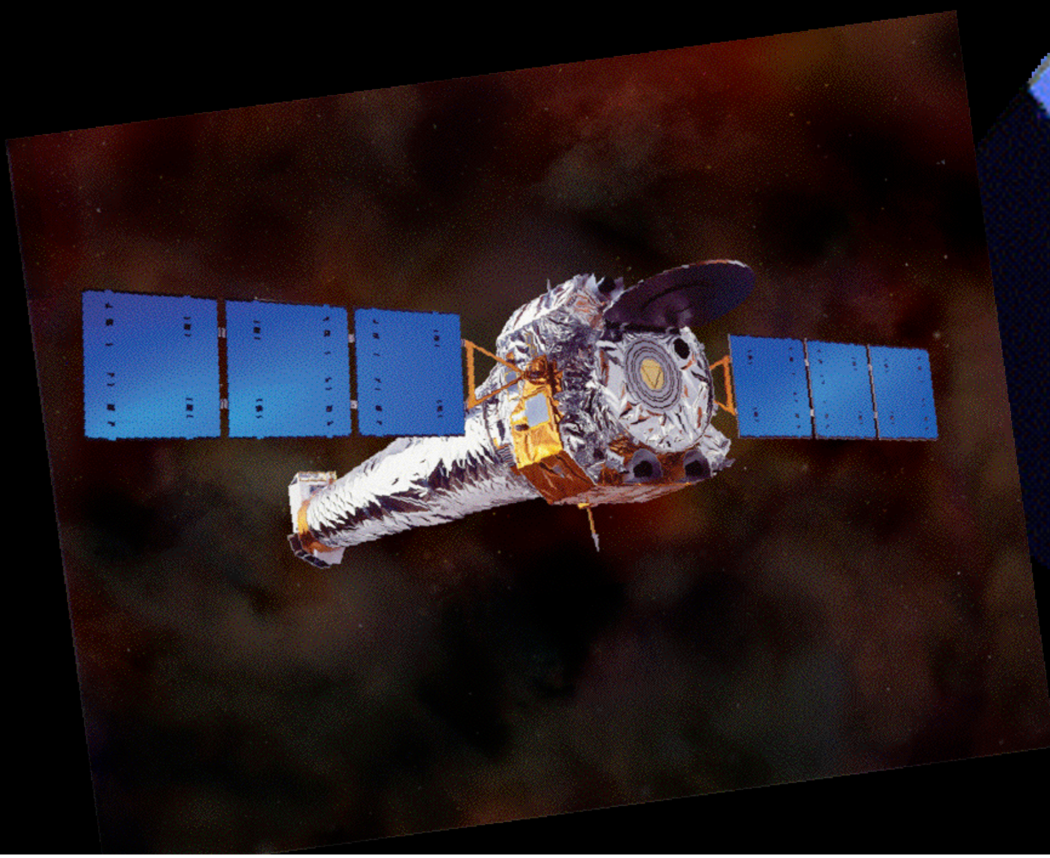
- ASCA (1993-2001) [0.4-10 keV]
- *Beppo*SAX (1996-2002) [0.1-300 keV]

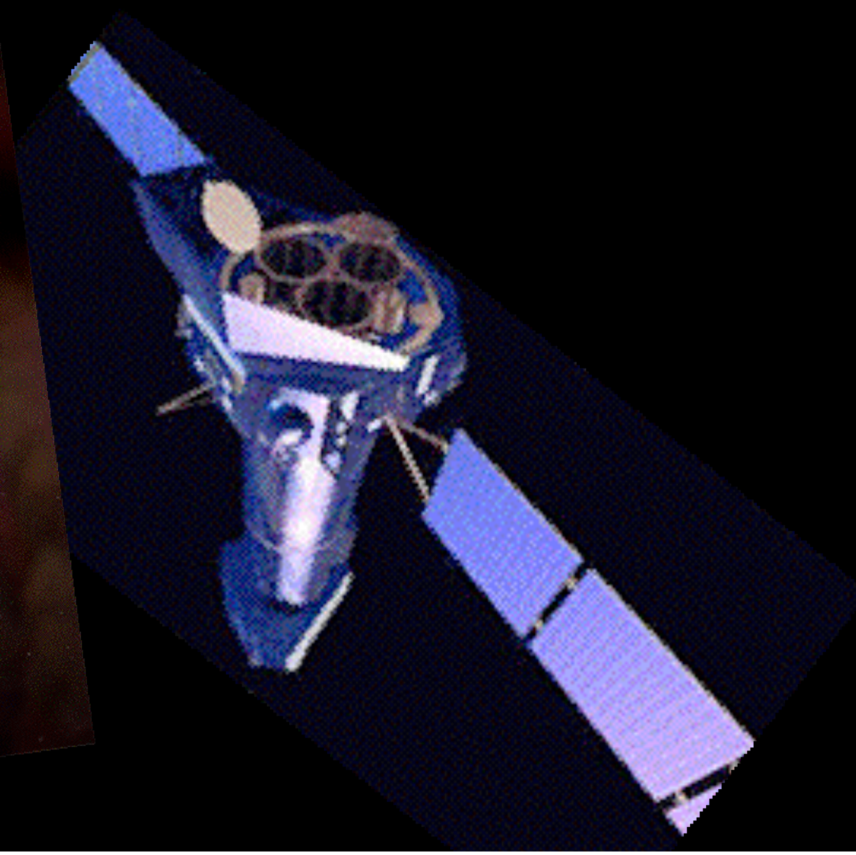




Chandra and *XMM-Newton* Surveys

- Chandra (1999-present)
- XMM-Newton (1999-present)





Chandra Advances

- 10-100_ fainter flux limits

  small PSF: less bkg and fainter confusion limit

- unambiguous source IDs

  subarcsec positions

- Source extent and morphology

XMM is complementary:

4_ Effective Area + larger Field-of-View
Harder energy band: 0.5-20 keV

The Extragalactic log-N-logS

$$N = \rho V = \left(\frac{\Omega}{4\pi}\right)\frac{4}{3}\pi\, D_{lim}^3$$

but

$$L = 4\pi\, D_{lim}^2 S$$

so

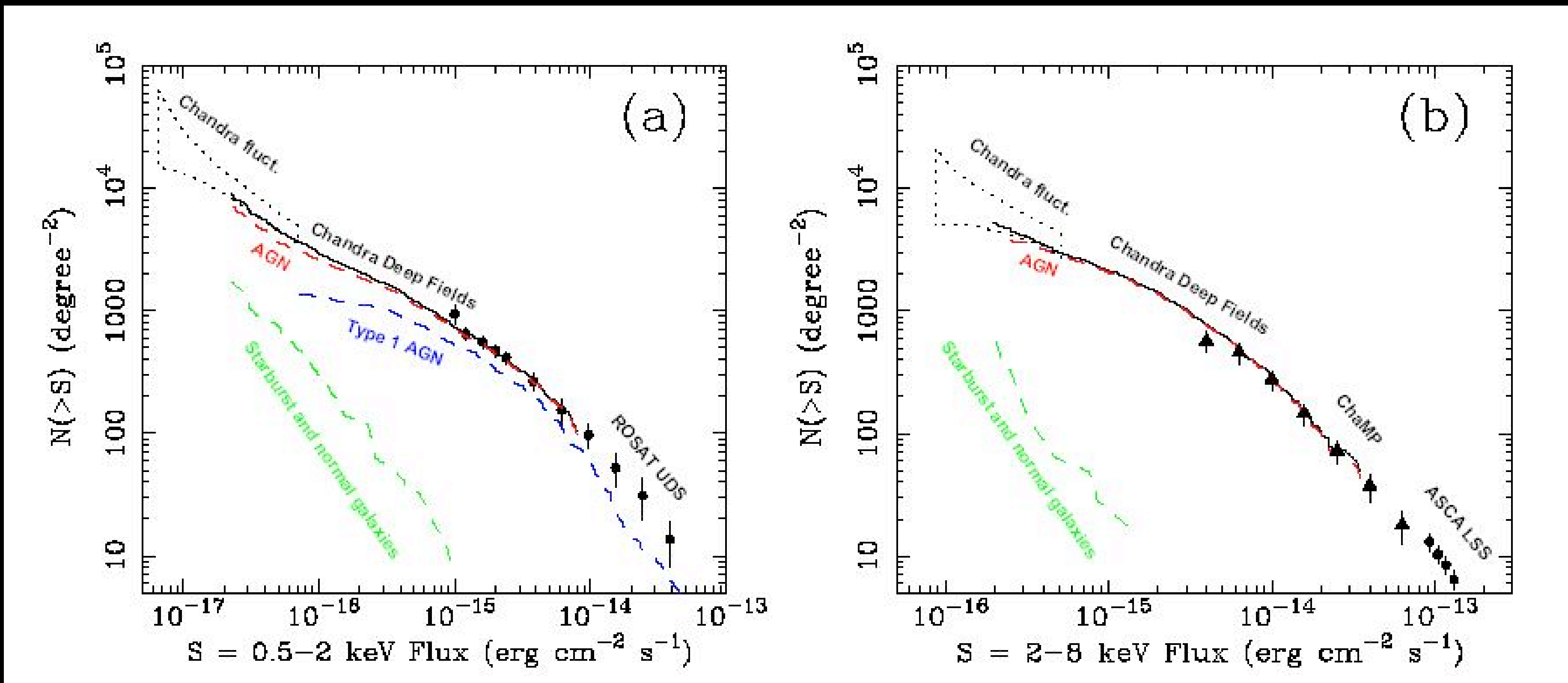
$$D_{lim} = \sqrt{\frac{L}{4\pi\, S}}$$

therefore

$$N \propto \rho\Omega\, L^{\frac{3}{2}}\, S^{-\frac{3}{2}}$$

So the slope of the log$N$-log$S$ curve should be $\frac{-3}{2}$ for a non-evolving population in an infinite, Euclidean universe!

X-ray log*N*-log*S*

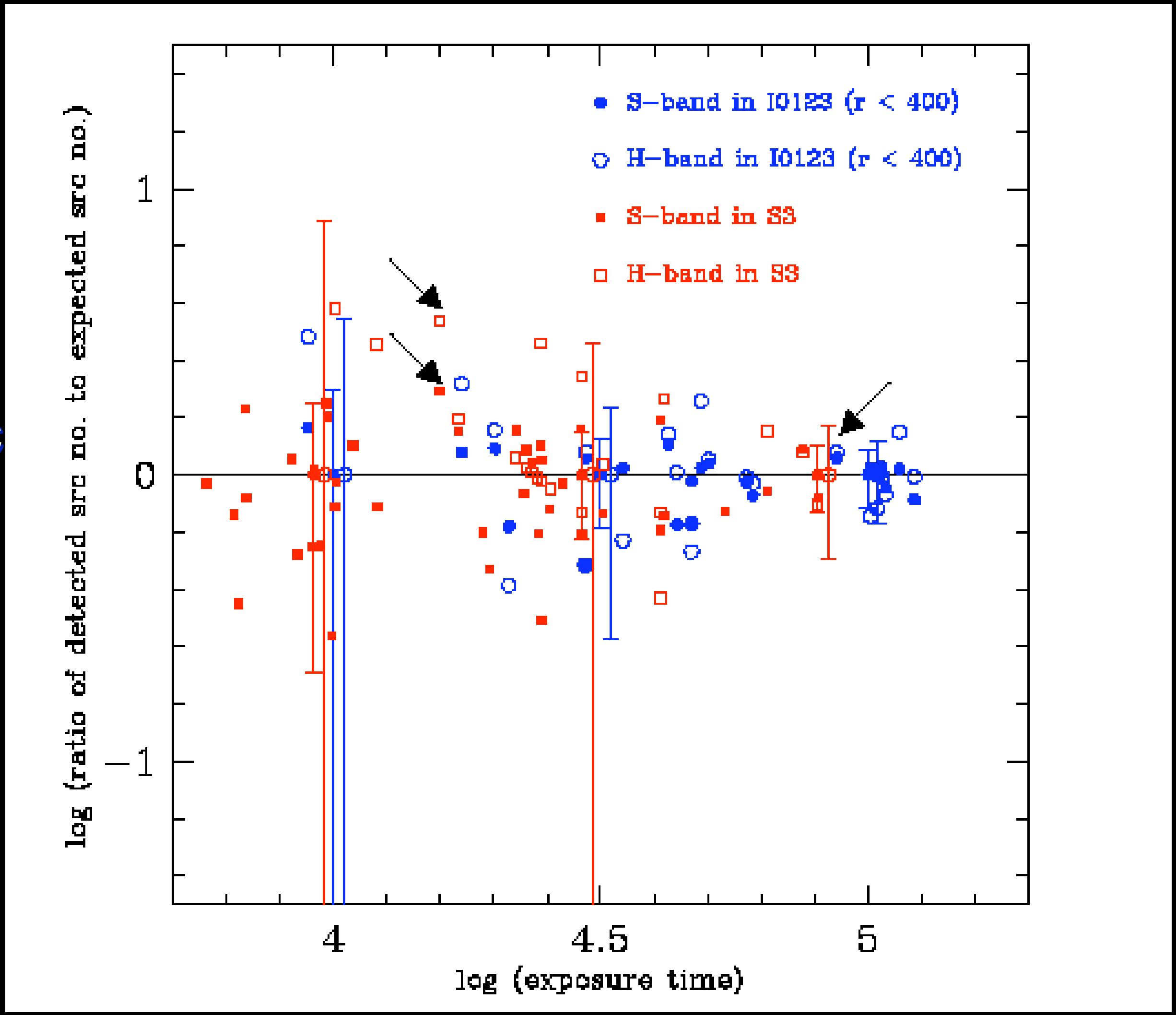


Fits require a broken powerlaw. For soft band

_$_{bright}$=1.6±0.2, _$_{bright}$=0.5±0.1, S_{break}~8_10^{-15}

Cosmic Variance?

- 62 fields
- counts>20; _<400”
- typical errors shown
- No significant Cosmic Variance!
- 3C295 cluster field exposures marked:
100ksec exposure belies earlier claim of overdensity



Kim et al. 2004

The Cosmic X-ray Background

- 1962 rocket flight to detect X-ray emission from the Moon discovers Sco X-1 and a diffuse cosmic background radiation (Giacconi et al.)

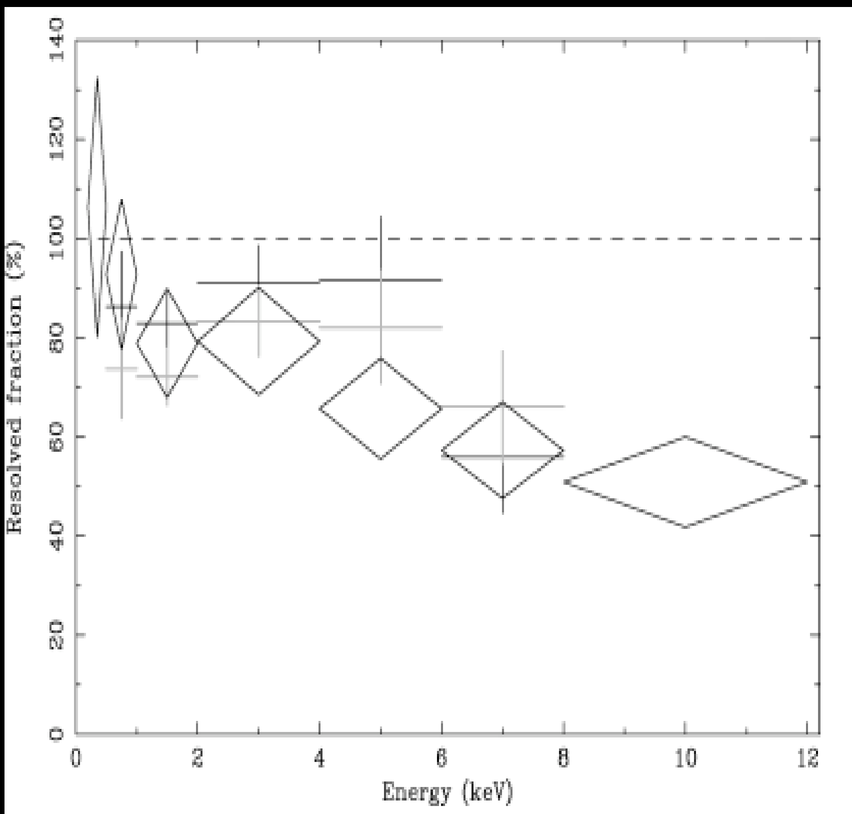
- Uhuru and Ariel V find isotropy: implies extragalactic, and large *N* required if discrete (Schwartz 1980)

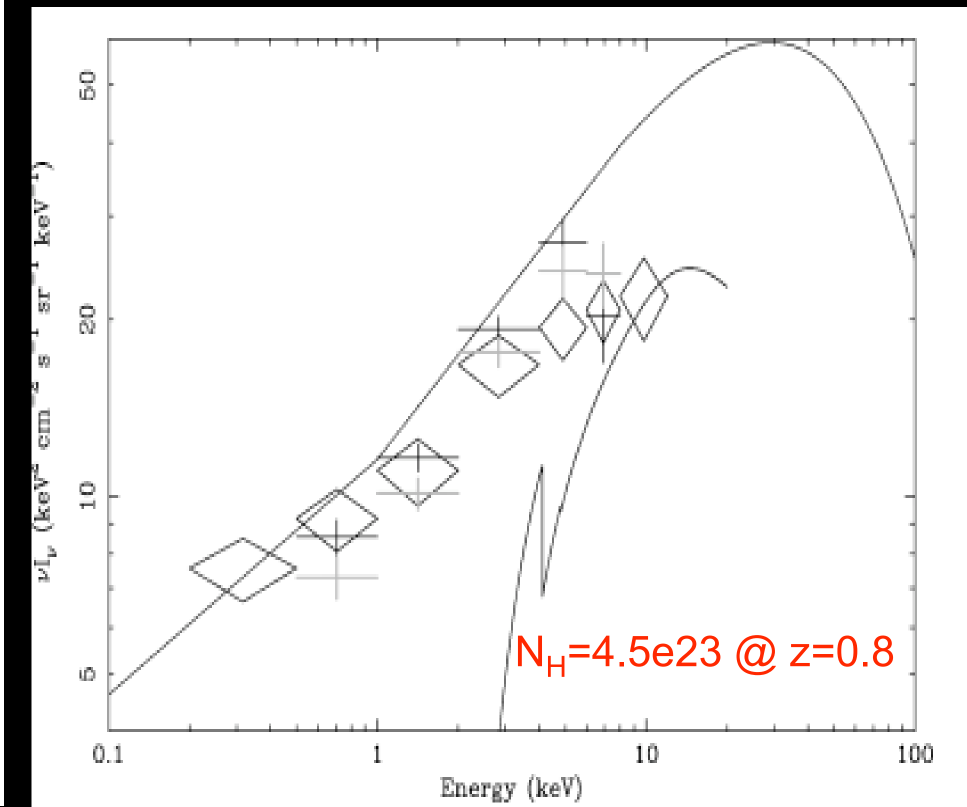
- HEAO-1 shows good fit w/ isothermal bremsstrahlung model kT~30keV (Marshall et al. 1980)

- *Not* from hot IGM gas, since expected CMB distortions not seen (Wright et al. 1994)

- *Not* from standard AGN =1.7 powerlaw spectrum… too soft!

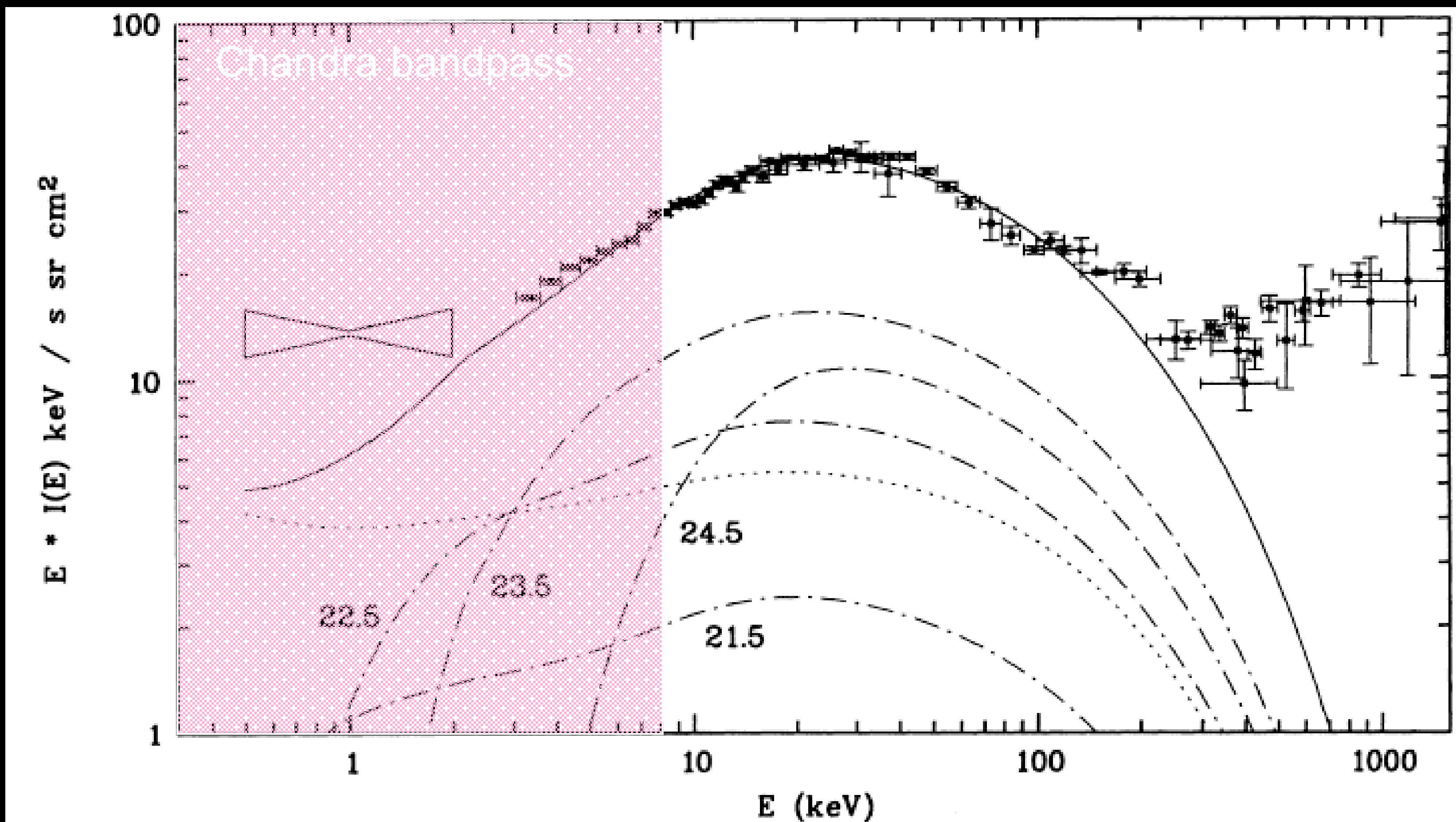
Resolving the Hard X-ray Background
(*XMM* and *Chandra* Deep Fields)





(Worsley et al. 2005)

The Cosmic X-ray Background and AGN Population Synthesis



Comastri et al. 1995

Science Motivations for X-ray Surveys

- Cosmological history of accretion
  - AGN across *L,z* plane
  - the when, where & how of high-z SMBH
  - AGN contribution to re-ionization
  - tie-in to current local bulge/SMBH
- Study populations contributing to the CXRB
- X-ray properties of normal galaxies and fraction w/AGN
- Find high-z clusters to constrain Cosmology
- Study cosmic variance and clustering
- History of star formation
- Detect mass limits of stellar coronal emission
- Find isolated neutron stars…

X-ray Survey Advantages

- X-rays penetrate large columns of gas and dust
  ($N_H \sim 10^{24}$ cm^{-2} ~ your hand)
- *Most* X-ray sources are AGN (high selection efficiency).
- ~*All* AGN produce X-rays (high completeness).
- Surface density of X-ray-selected AGN exceeds optical AGN by 10-20x (Bauer et al 2004)
- X-rays sample the circumnuclear region ($R<100*R_{grav}$)
- No strong z-dependence like optical

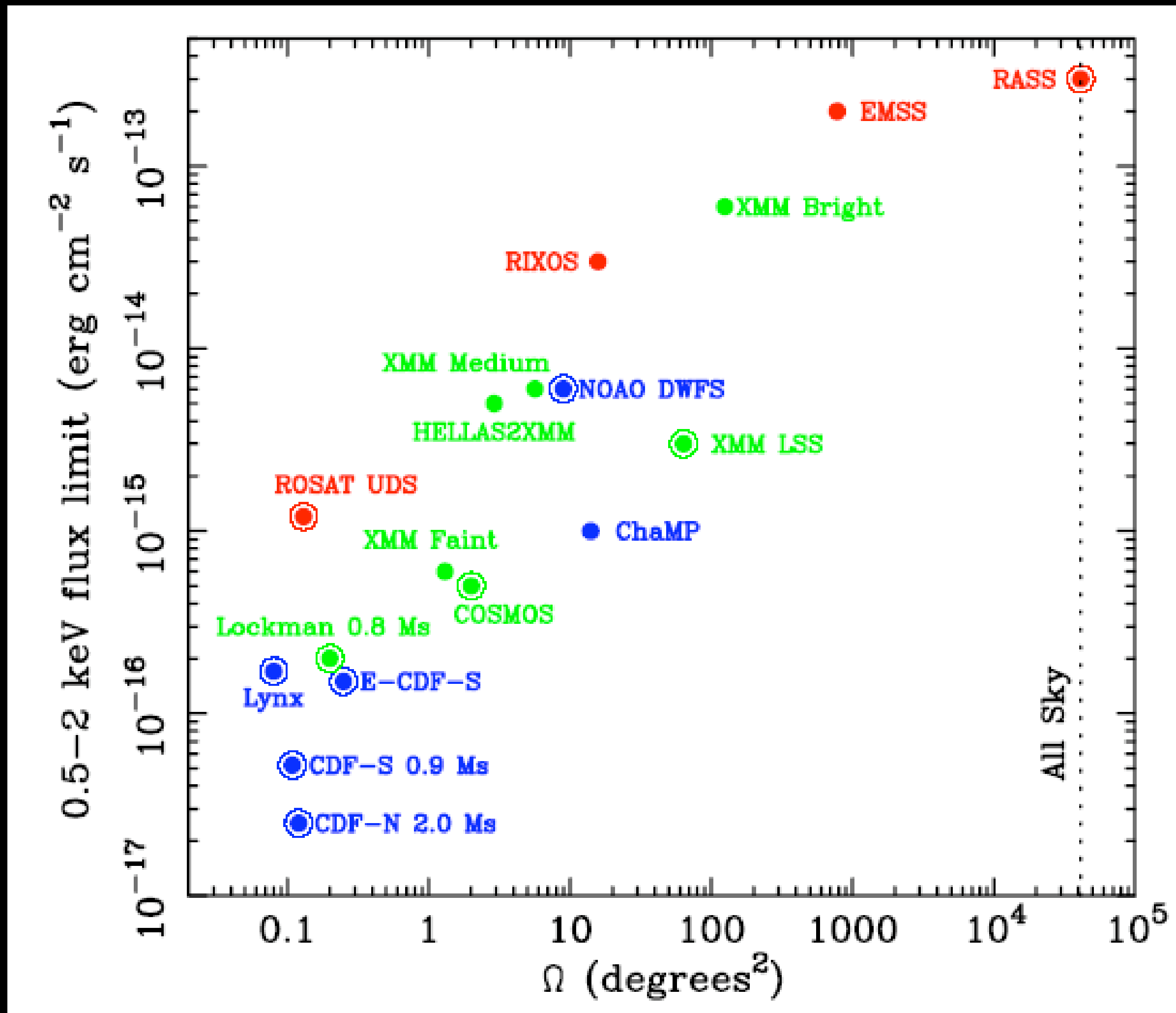
$$N_H \sim N_H / (1+z)^{2.6}$$

- X-ray spectral information comes for 'free'.

X-ray Survey *Bummers*

- X-ray detectors are non-uniform
  - PSF size and flux sensitivity vary with off-axis angle
- Deep or wide X-ray surveys are expensive & time consuming
  - use serendipitous detections from archived observations
- Require multi-wavelength followup

Extragalactic X-ray Surveys



Deep Extragalactic X-ray Surveys

- Pencil-beam surveys probe early cosmic epochs
- Low-luminosity, more typical object types are detected
- Resolve largest possible fraction of CXRB
- Provide signpost data for future missions

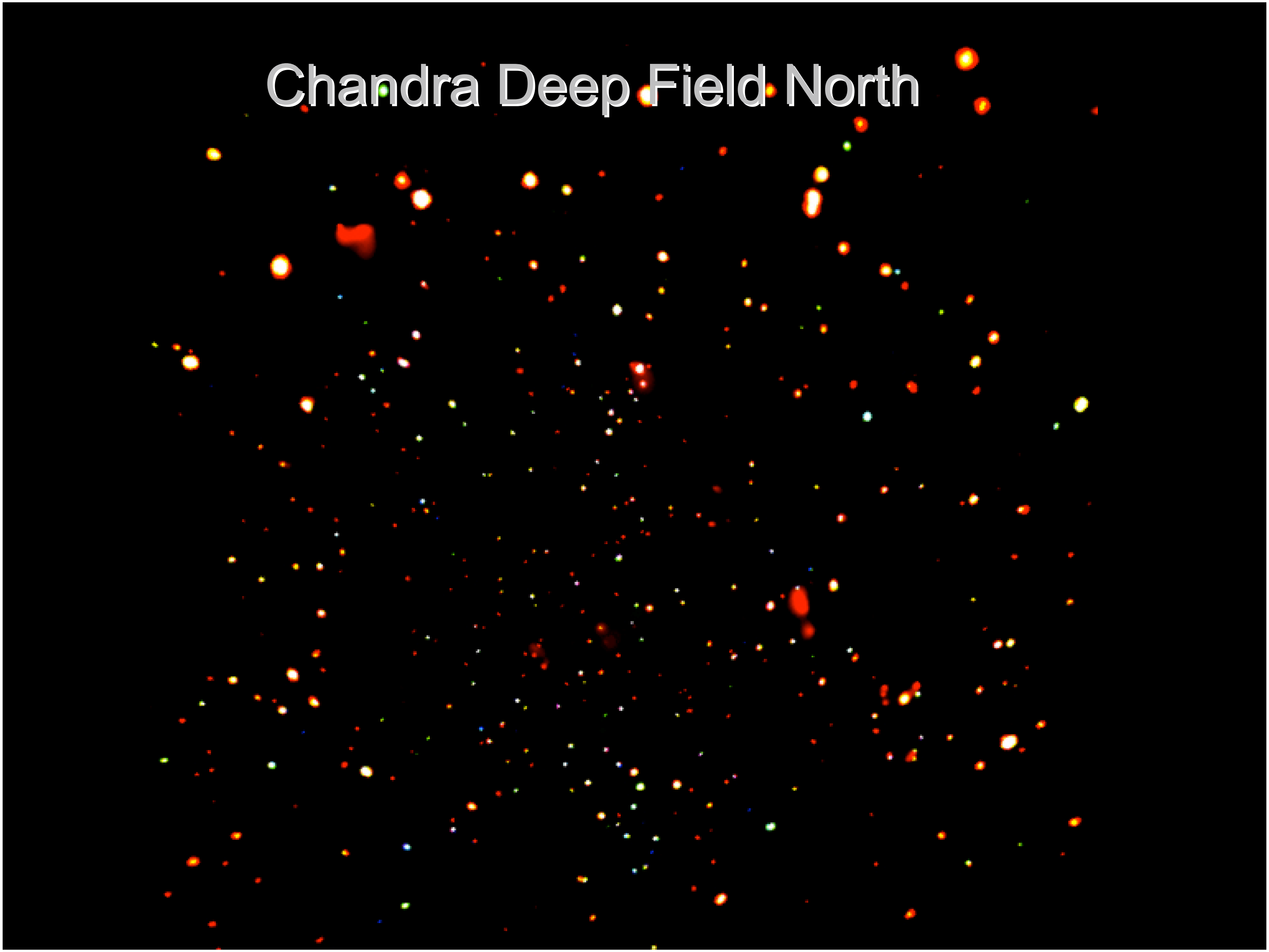
Deep Extragalactic X-ray Surveys (>75ksec)

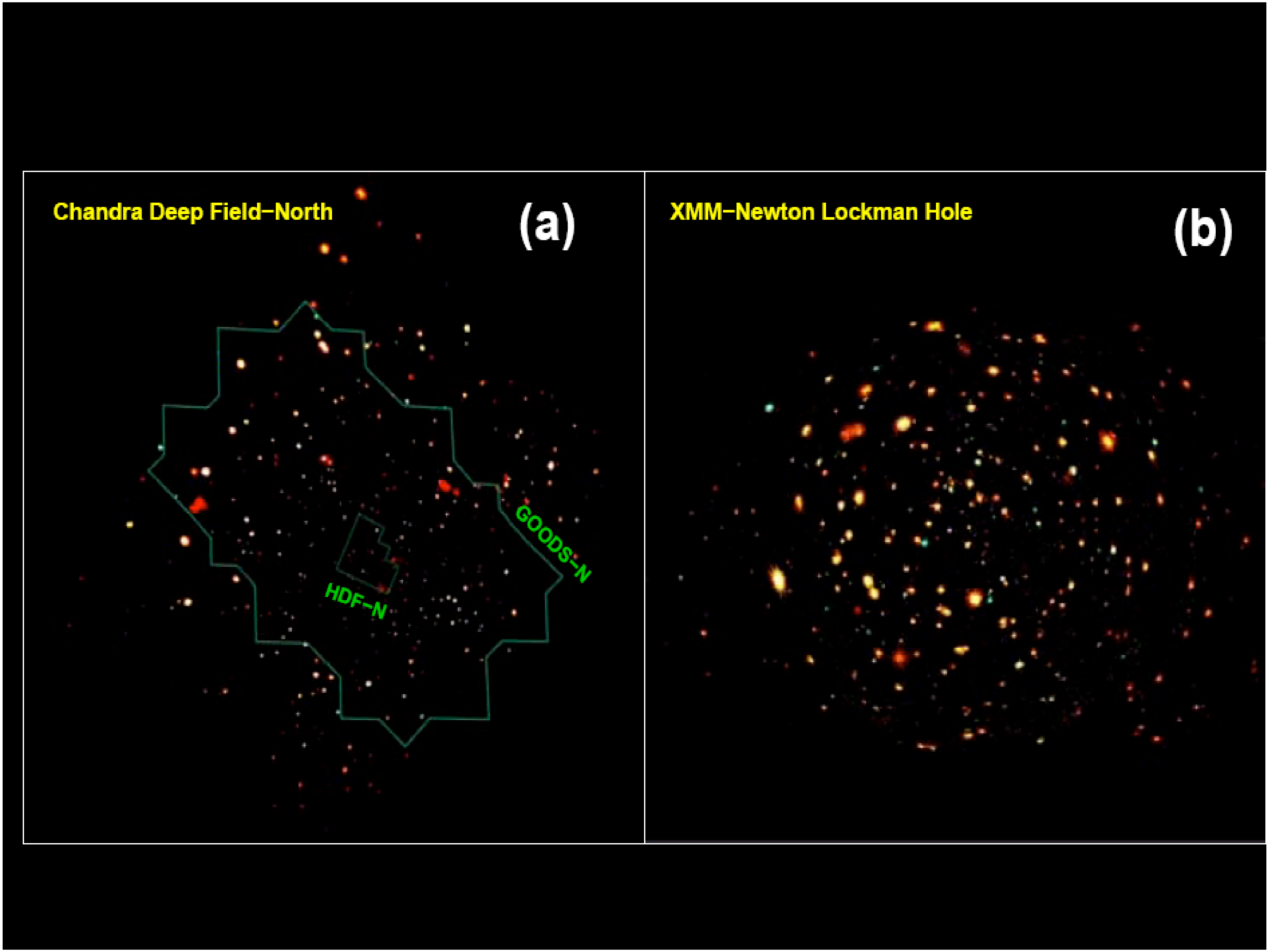
Table 1: Deep Extragalactic X-ray Surveys with *Chandra* and *XMM-Newton*

Survey Name	Max. Eff. Exp. (ks)	Solid Angle (arcmin^2)	Representative Reference or Note
		Chandra	
Chandra Deep Field-North	1950	448	Alexander et al. (2003b)
Chandra Deep Field-South	940	391	Giacconi et al. (2002)
HRC Lockman Hole	300	900	PI: S.S. Murray
Extended CDF-S	250	900	PI: W.N. Brandt
Extended Groth Strip	200	1800	Nandra et al. (2005)
Lynx	185	286	Stern et al. (2002a)
LALA Cetus	174	428	Wang et al. (2004b)
LALA Boötes	172	346	Wang et al. (2004a)
SSA13	101	357	Barger et al. (2001a)
Abell 370	94	357	Barger et al. (2001b)
3C 295	92	274	D'Elia et al. (2004)
SSA22 "protocluster"	78	428	Cowie et al. (2002)
ELAIS N1+N2	75	586	Manners et al. (2003)
		XMM-Newton	
Lockman Hole	770	1556	Hasinger (2004)
Chandra Deep Field-South	370	802	Streblyanska et al. (2004)
Chandra Deep Field-North	180	752	Miyaji et al. (2003)
13 hr Field	130	665	Page et al. (2003)
Subaru *XMM-Newton* Deep	100	4104	PI: M.G. Watson
ELAIS S1	100	1620	PI: F. Fiore
Groth-Westphal	81	727	Miyaji et al. (2004)
Marano Field	79	2140	Lamer et al. (2003)
COSMOS	75	7200	PI: G. Hasinger

Brandt 2005 ARAA

Chandra Deep Field North




Chandra Deep Field−North
(a)
GOODS−N
HDF−N
XMM−Newton Lockman Hole
(b)

Wide Extragalactic X-ray Surveys

- Amass rare source types and luminous high-z objects
- Allow for studies of clustering and cosmic variance
- Bridge flux gap between deep and all-sky surveys
- Still sufficiently deep that complete source classification is quite challenging

Wide Extragalactic X-ray Surveys

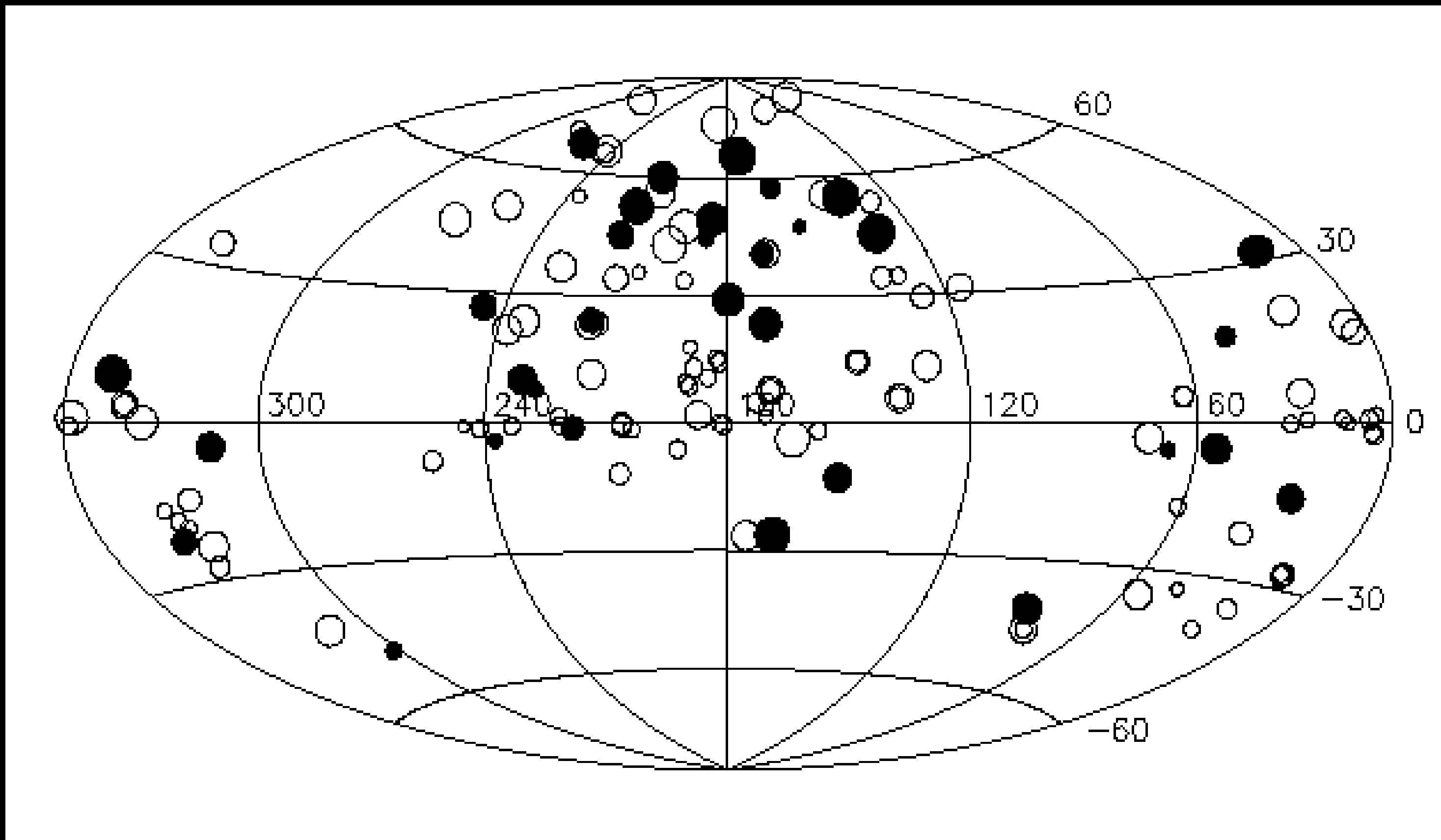
Chandra

- ChaMP (Green et al. 2004; Kim et al 2004)
- CYDER (Treister 2005)
- CLASXS (Lockman Hole; Steffen, Barger, Yang)
- XBootes/NDWFS (Murray, Jones, Kenter, Brand)
- SEXSI (Harrison, Helfand)

XMM-Newton

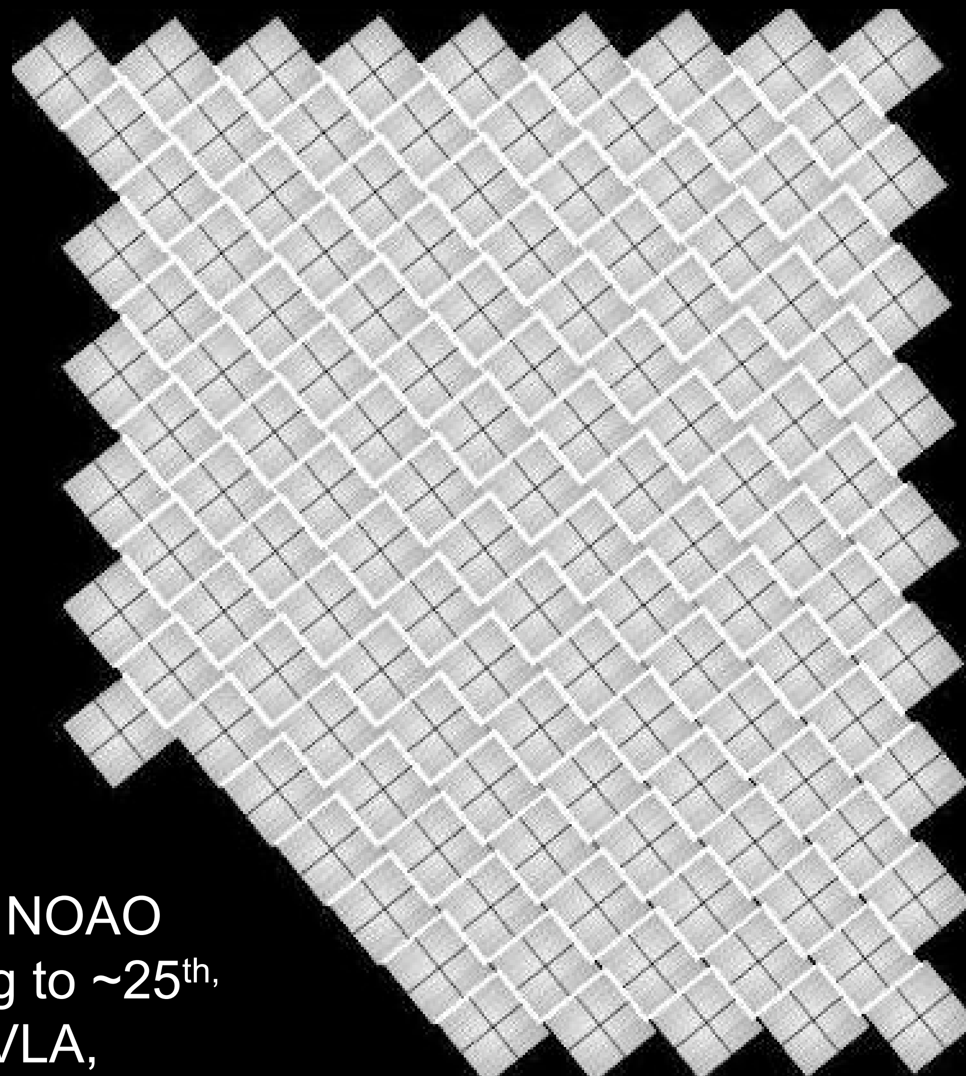
- HELLAS2XMM (Baldi, Fiore, Brusa)
- XMM/2dF (Georgakakis, Georgantopolous)
- XMM-SSC (Watson)
- XMM-LSS (Pierre)

ChaMP Field Distribution



- 130 Cycle 1&2 ACIS Fields: ~14 sq. deg
- Exposure times 2-190 ksec
- ~6000 X-ray sources

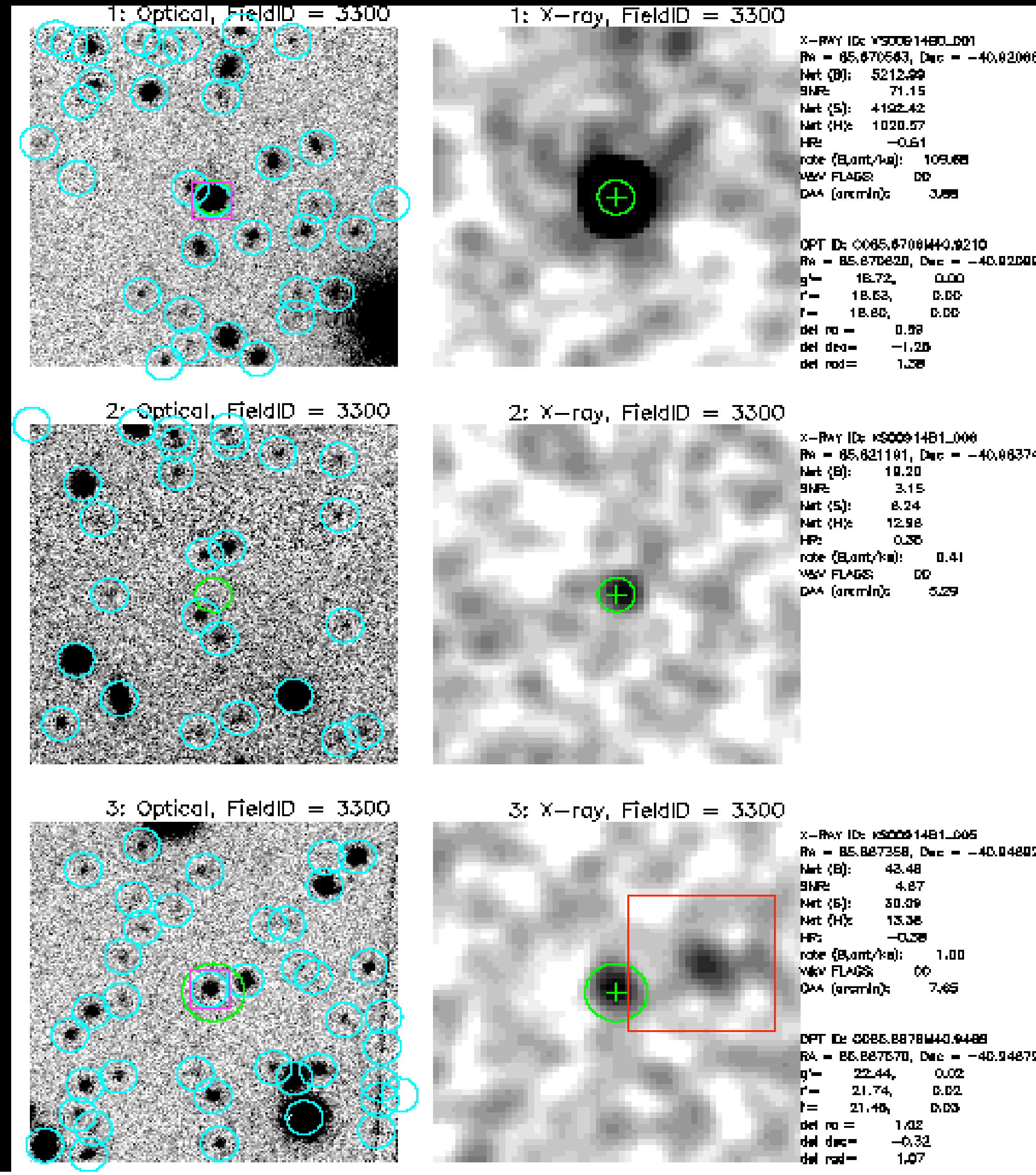
XBootes 126*5ksec Chandra Raster



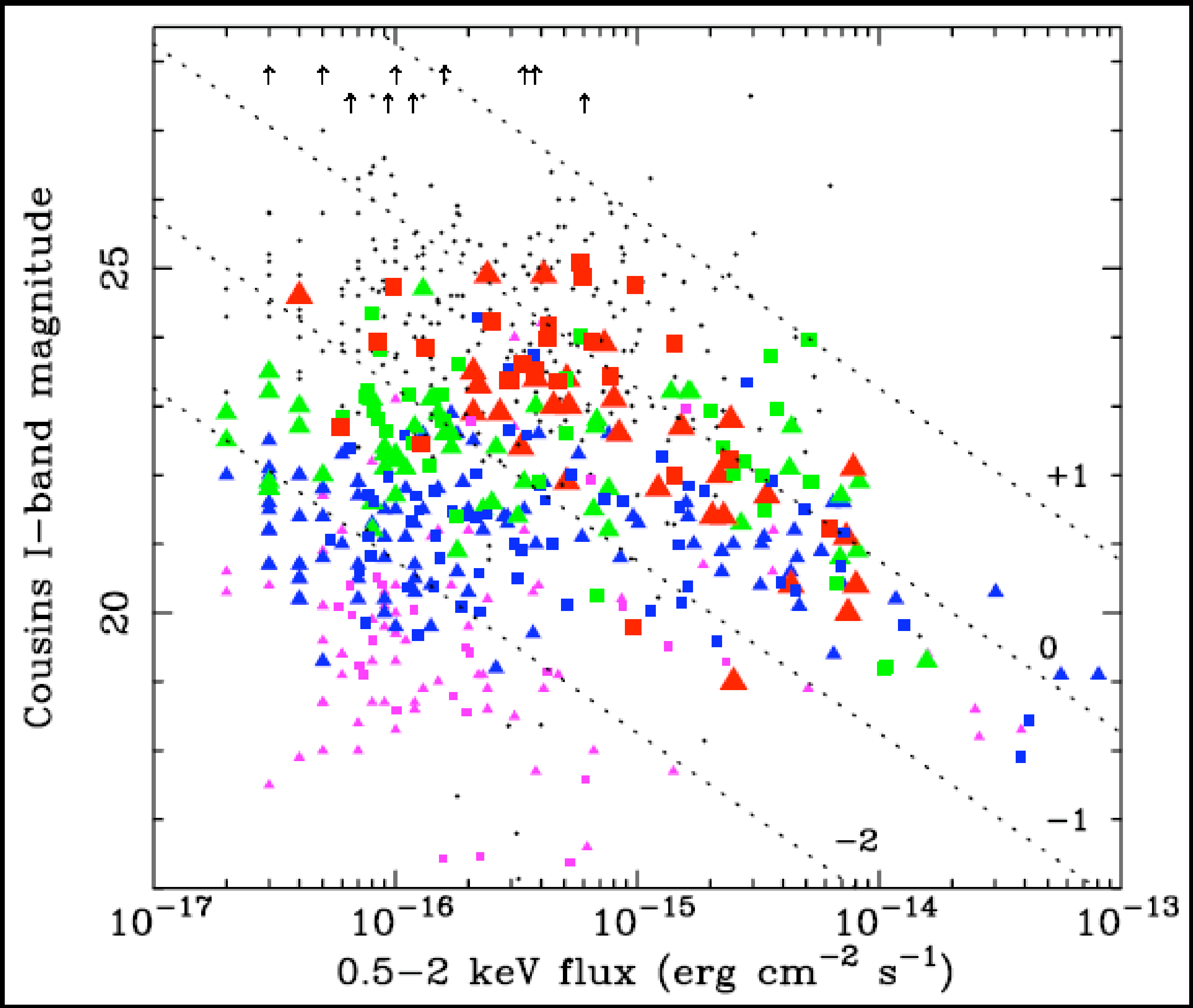
9deg^2 also covered by NOAO
B_w,R,I Mosaic imaging to ~25th,
JHK to ~20th, Spitzer, VLA,
Galex…

X-ray/Optical Matching

- **Very sensitive to PSF size**
- **Match / multiple/ spurious fractions all depend on relative flux limits**
- **Demands visual inspection**



X-ray/Optical Source Properties



REDSHIFT

0 - 0.5

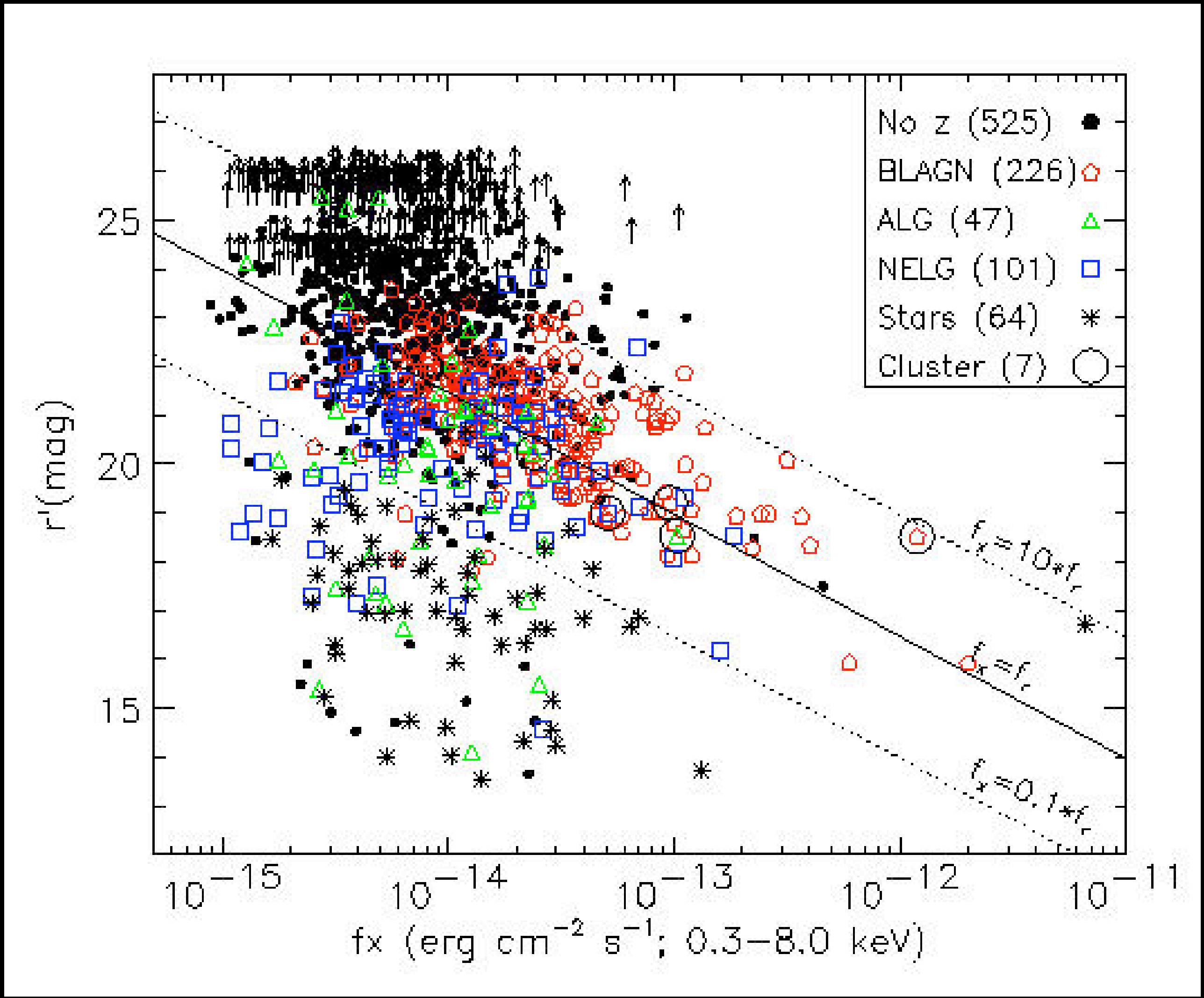
0.5 - 1

1 -- 2

2 -- 6

Brandt 2005 ARAA

Source Types



- 24 Fields
- 445 zs
- 52% BLAGN

Broad emission Line AGN (FWHM > 1000 km/s)

- 25% NELG

Narrow Emission Line Galaxy (FWHM<1000 km/s; W^e_λ>5 Å)

- 11% ALG

(absorption line galaxy)

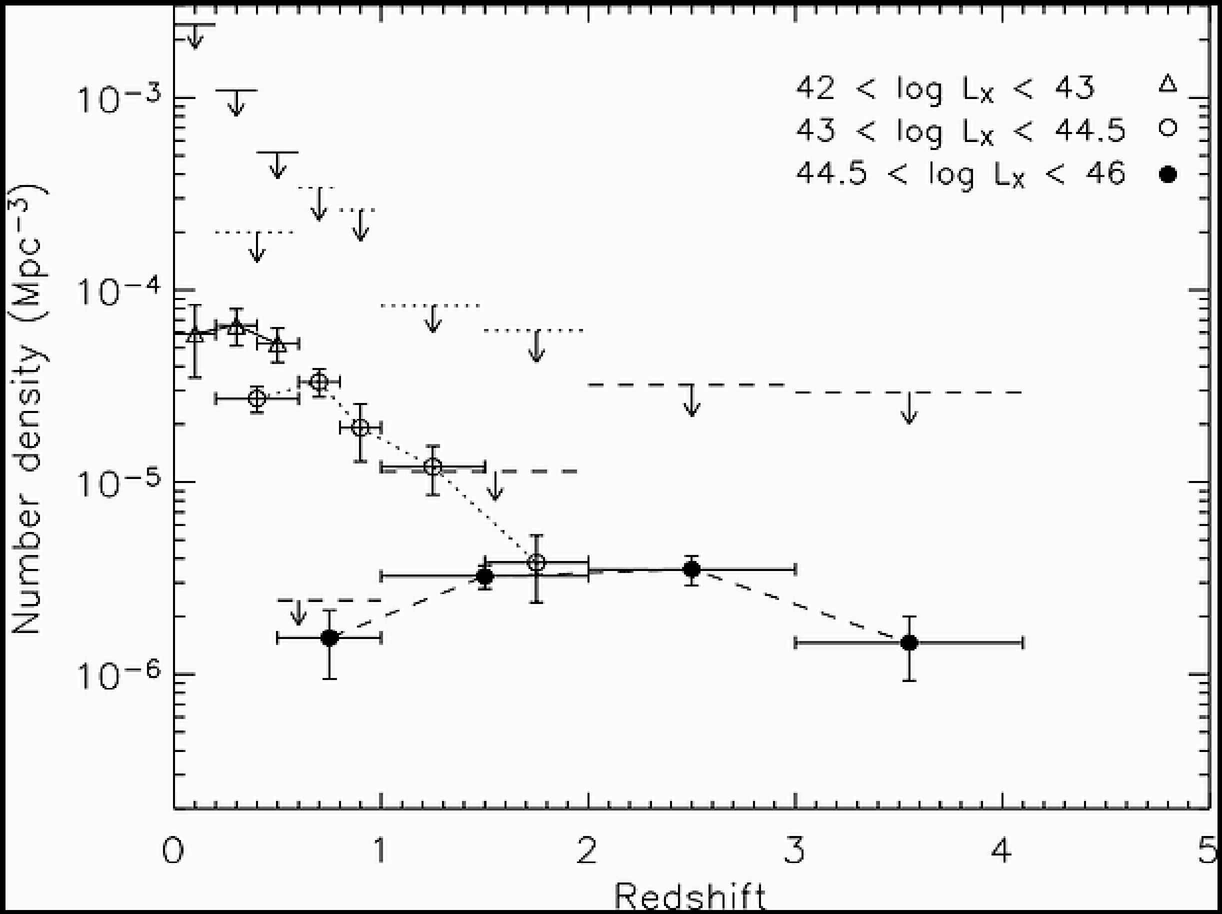
- 13% Stars
- 1% Clusters

from ChaMP - J. Silverman (MPE), P. Green (SAO), et ll

Basic **AGN** Types from X-ray Surveys

- Unobscured AGN
- Obscured AGN with clear optical/UV AGN signatures
- Optically faint X-ray sources
- XBONGs (X-ray Bright Optically Normal Galaxies)
- AGN unification is “broken” between optical (type1 and type2) and X-ray (unobscured and obscured)

X-ray AGN Comoving Space Density (0.3-8.0 keV)



- **Low luminosity AGN more prominent at z < 1**

  Cowie et al. 2003, Ueda et al. 2004, Fiore et al. 2004

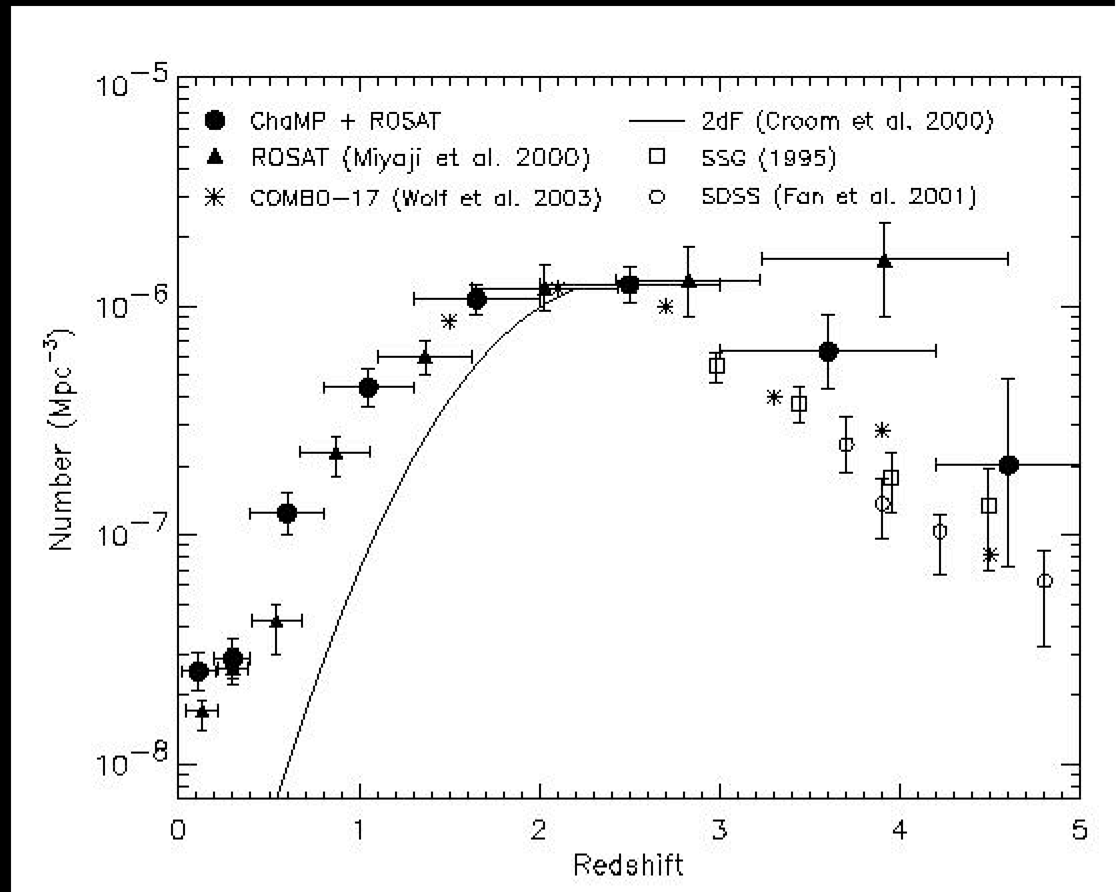
- **First detection of a turnover in the space density of luminous QSOs at z > 3**

  Silverman et al. 2005

Space Density of X-ray Luminous QSOs

Combined 0.5-2keV Sample

1004 AGNs



Optical - scaled to match X-ray at z=2.5

***ROSAT* survey** (Miyaji et al. 2000)

Compilation of deep and shallow

surveys: **690** AGN.

Only 7 QSOs with z > 3. Four were detected in the Lockman Hole (Lehmann et al. 2001)

Chandra

279 ChaMP + 43 CDF AGN
6 with log Lx > 44.5 and z > 3

Note: 25 *Chandra* fields reach similar depths to smooth over cosmic variance

X-ray Luminosity Function

$$\phi(L,z) = \frac{d^2N}{dV\,dL}(L,z)$$

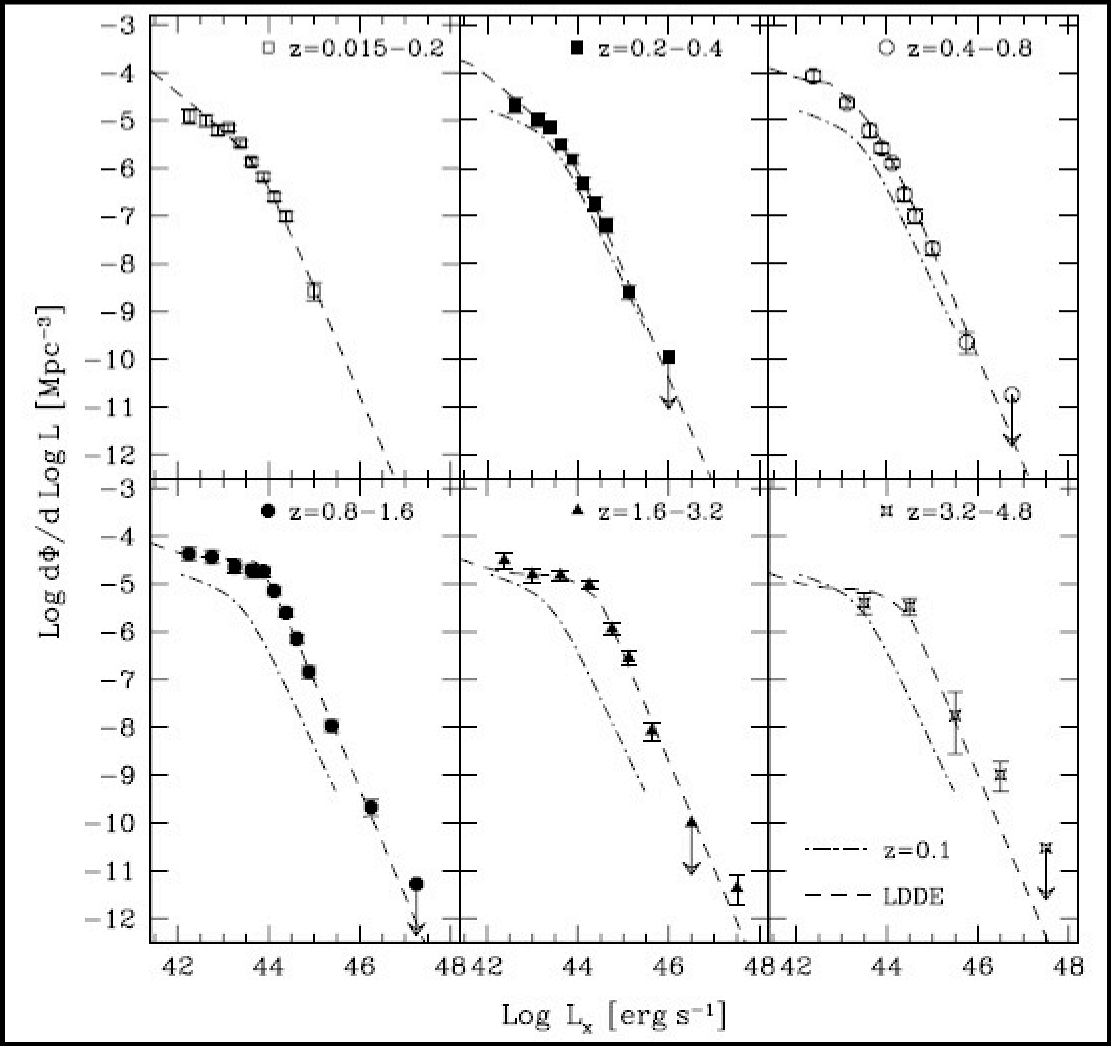
***1/ V_a* method**

$$\phi_{1/V_a}(L,z) = \frac{1}{\Delta \log L}\sum_{i=1}^{N}\frac{1}{C(i)V_a(i)}$$

$$V_a = \int_{z_1}^{z_2}\frac{dV_c}{dz}\,dz\,d\Omega$$

<u>Identified fraction</u>

0.3 < C(i) < 1.0



Brandt & Hasinger 2005, ARA&A;
LDDE fit shown as dashed curve

Current & Future Projects

- Evolution of AGN X-ray properties
- Clusters from optical *and* X-ray images
- Lenses, pairs, jets
- Variability studies
- AGN-AGN and AGN-galaxy clustering…

The Chandra Multiwavelength Project (ChaMP) - Mozilla

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Home Bookmarks The Mozilla Or... SuSE - The Lin...

ChaMP

Science Goals

Survey Strategy

Results & Papers

Education/Outreach

The unprecedented spatial resolution and sensitivity of the Chandra X-ray Observatory provides a rich archive of serendipitous sources. The ChaMP seeks to understand the nature and evolution of quasars, galaxies, and clusters of galaxies in a large, carefully constructed multi-wavelength survey. A team of scientists, led by staff members at the Chandra X-ray Center (CXC) with collaborators from NOAO, MIT, MMTO, SDSS, UofA, MSU, OSU, Ohio, UT, Rome, Italy and Bristol, UK, is carrying out a multi-wavelength identification program for these X-ray sources.

As well as the extragalactic study, a similar Galactic Plane survey, ChaMPlane, is being led by Josh Grindlay

NEW ChaMP detects highest redshift X-ray selected object!
(ApJ,**569**,L1)

ChaMP Contact Information:

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- Co-investigators: Full list of co-Is

Home | Science Goals | Survey Strategy | Results & Papers | Education/Outreach | Internal Page (password access only)

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